Weatherwise

Sailplane Weather

Weather Helps Establish Sailplane Records

When Summer Commences

The Donora Smog Disaster

Thunderstorm Today? - - Try a Probability Forecast

Vol. 1, No. 3, June, 1949

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE" — BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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Weatherwise and the AMS

WEATHERWISE has been distributed during the past 16 months to all members of the American Meteorological Society as a privilege of membership. At its reorganization in 1944, the AMS recognized the need of a magazine of a popular nature that would present the problems and progress of meteorology to the general public, but adequate financial resources and suitable editorial personnel were not available.

To fill this need, **Weatherwise** was started by the Amateur Weathermen of America in February, 1948. The council of the AMS welcomed its appearance and felt that **Weatherwise** fulfilled the requirement for a popular journal. Accordingly, a block subscription was arranged and free distribution to members commenced, the cost being met in part by the gift of an anonymous donor and in part from surplus publication funds.

Greatly increased costs incurred this winter in publishing the **Bulletin** of the society in revised format and the **Journal of Meteorology** with increased pages have necessitated a complete review of AMS publication policies. As one measure of economy, the free distribution of **Weatherwise** will cease with the present issue. Members of the AMS who wish to receive this magazine for the remainder of 1949 are asked to send one dollar to the office of the executive secretary of the society. In 1950, a special reduced subscription rate for **Weatherwise** will be extended, the rate depending on the number of AMS members subscribing.

Close co-operation between the AMS and the AWA has existed since the founding of the AWA in 1946, and it is hoped that this will strengthen and expand. **Weatherwise** will continue to serve as a medium for the exchange of news and information between the professional and the amateur meteorologist. The AWA also publishes **Weatherwatch**, a monthly chronology of weather events. The subscription for 12 issues is $1.25.

D. M. L.

AMS TO MEET AT VANCOUVER

The 103rd national meeting of the American Meteorological Society will take place in Vancouver, B. C., on June 15 and 16, 1949, with the 30th annual meeting of the Pacific Division of the American Association for the Advancement of Science (June 13-18). The Puget Sound branch of the AMS and the meteorologists of Vancouver, B. C., are joint sponsors of the event. The general sessions and the meeting of the affiliated societies will be held at the University of British Columbia.

Hotel reservations are scarce and should be made as early as possible directly with the hotels: Hotel Vancouver, Hotel Georgia, Hotel Devonshire, Hotel Grosvenor, and Ritz Apartment Hotel. Also accommodations will be available in the University Camps at $1.50 per person per day. Reservations for accommodations in the camps will be accepted in order of application and confirmed by mail if time permits, if application is made to the Extension Department, University of British Columbia, Vancouver.

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Cover: A sailplane taking off in good soaring weather at Elmira, N. Y. Photograph by Fred T. Loomis. (See page 51.)

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Clouds associated with the Owens Valley standing wave, observed southward from the airport at Bishop, California. The central cloud was stationary for 10 hours, about 25 miles away, with its base 9,000 feet above ground. The lenticular cloud was about 40,000 feet high. The wind was blowing from the west over the Sierra Nevada range at the right. All engravings in this article are from the magazine *Soaring*, courtesy of the Soaring Society of America.

Sailplane Weather

B. L. WIGGIN, UNITED STATES WEATHER BUREAU, BUFFALO, NEW YORK

IN YOUR COMMUNITY you may not have the long, surging ocean swells of the beach at Waikiki, nor the fast twisting bobsled runs and slalom slopes of St. Moritz, Lake Placid, or Sun Valley. But you do have sports trails with a thousand times the thrills of surfboarding, bobsledding, or skiing. They are as safe to use. Many are in good shape 12 months of the year.

Professor Albert Zahm was sliding down these trails over the Notre Dame campus in 1888. Another professor, John J. Montgomery, had led the way in 1883 at San Diego. And the Wright brothers flew the glider that grew up to become the first successful airplane.

Gravity powers the glider and the sailplane. It's the same *g* that dropped the apple on Newton's head. It is the prime mover in nature's realm, today as yesterday. It pulls things down. All aircraft are pulled earthward by gravity. Their wings produce *lift* as they speed through the air. In level flight the lift produced by the wings balances the constant pull of gravity. In powered aircraft, motors simply pull or push the wings through the air at high speeds so that great amounts of lift are produced. Stop the motors and gravity takes over to end the flight.

But a sailplane is maintained in beautiful noiseless flight. Gliders and sailplanes have larger wings, produce more lift for a given speed. Twenty-five to 40 miles per hour will keep most of them sailing. If the pilot chooses, he can fly 100 to 150 miles per hour, then drop to a landing almost as slowly as a bird.

Primary gliders are rugged and heavy.

They are the only conventional aircraft designed to fly low and slow. There are intermediate types leading to the sailplane, which is a poem of functional line and form. To glide through the air one needs only the wind and an obstacle like a ridge or sand dune. The wind in passing over is forced to rise. A glider launched into the up-current of air can stay aloft as long as the wind blows. The pilot may rise as much as four times the height of the obstacle. He may find rising air extending a considerable distance upwind from it. So long as the wind-driven air is rising as fast or faster than the glider falls, the ship remains airborne. Records of over 50 hours of flight have been made in such winds.

It's more fun to sail off and see what's beyond the ridge — go cross country. For this one takes the sailplane with its long, tapering wings and streamlined fuselage. In Russia a girl made a flight of nearly 500 miles in a sailplane. The present United States record is under 400 miles. Most of the international records are held by Russia, where interest in aviation supports a popular glider program.

To make such flights a rather specialized knowledge of weather is needed so as to take advantage of nature's generous power plant. Cold air in contact with the surface of the earth simmers and boils when it is heated. Heating is not uniform; for example, pavement under the direct rays of the sun gets much hotter than the grassy strips beside it. Fallow land gets warmer than a field of wheat, and both get much hotter than a grove of trees. All three get hotter than an extensive water surface such as a lake or swamp.

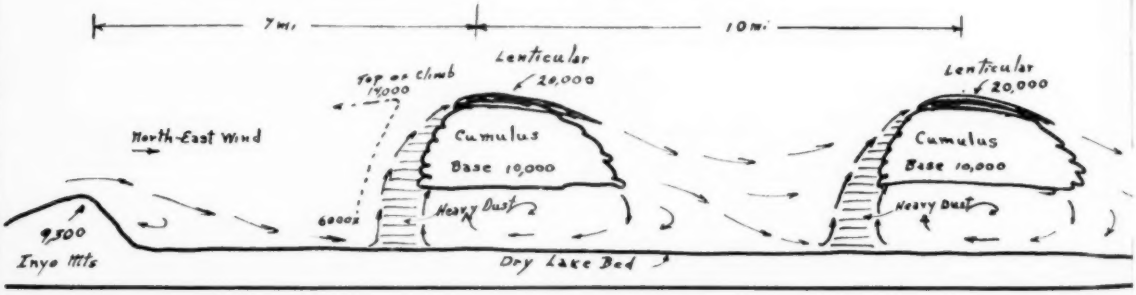
Blobs of heated air become buoyant; then gravity moves the colder, denser air under them and they balloon upward. A complex process combines small rising air masses into larger columns, which are the *thermals* the cross-country sailplane pilot uses. They range in size from a few feet in diameter up to a few miles. The small ones prevail in the morning, large ones during the second half of the day. Strong winds and divergent airflow both operate to prevent large diameter thermals from forming.

The pilot detects the strongest thermals by feel as the ship rises in them like a soaring gull. Weaker thermals are detected by a variometer, an instrument which indicates change in air pressure — if the pressure is falling the ship is rising. The sport is to stay within the limits of the rising air columns.

As air rises, its temperature and pressure fall off. So long as the surrounding air is colder, the rate of upward motion increases until it reaches levels where the surrounding air becomes warmer. In some cases, rising air may go all the way to the stratosphere before its accelerations are stopped.

If there is enough water vapor in the rising column, some condenses out to form cumulus. These clouds are the route signs for a cross-country flight, marking as they do the upward heads of fountains of air. Sometimes a small cumulus continues to grow at the expense of other small cumuli around it. Eventually it may become a thunderstorm. Only pilots trained to fly on instruments, and in ships strong enough to withstand wracking stresses ever venture into the cumulonimbus, or thunderstorm cloud. Within it may be vertical currents of over 50 miles per hour. Heights of over 30,000 feet can be reached in a sailplane using a thunderhead as an escalator. But if you are clumsy! One such pilot stated his experience in a small, incipient thunderhead. "It was as if I were in a canoe on a pinwheel on a rocket."

Cloud streets are formed in the sky when



Paul MacCready, holder of the international soaring goal and return record, off to the Bishop standing wave in an Orlik sailplane. Photograph by Robert Symons.

the winds aloft increase at the right rate. Then random clouds become arranged in long strips parallel to the wind. Motion of the air in these cells is a spiral in the direction of the wind. The clouds mark the rising air: clear spaces between the streets almost surely are zones of sinking air. In September, 1941, Major Floyd Sweet and I sailed over the more desolate parts of Pennsylvania with never an uneasy moment, for the sky was like a ploughed field, the furrows being the cloud streets we followed.

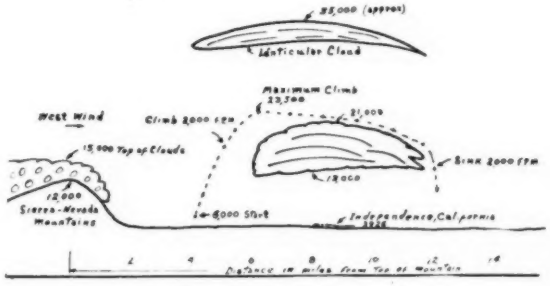
From ridge winds to thermals to cloud soaring, devotees of the sport have pushed forward the records for distance, altitude, and speed. More recently, gravity waves have been used to make outstanding flights on days when there have been inadequate thermals. In 1939 German glider enthusiasts were already exploring *standing waves*. The next year, a flight of 37,000 feet and into the stratosphere was achieved by soaring in a wave in the lee of the Alps.

A series of waves extending downstream marks where flowing water meeting a rock, or similar obstruction, flows on over it. Analagous waves are formed in the air under favorable temperature conditions. Fortunately for sailplane pilots, these standing waves occur most often when thermal activity is inhibited or reduced to a shallow layer near the surface. The waves become partly visible when a characteristic lenticular cloud forms near or at the crests. Although the wind may be strong, the cloud is apparently motionless; actually it is constantly dissipating on the lee side while forming on the windward side. Secondary and tertiary waves sometimes form farther downstream.

The amplitude and length of barrier-induced waves depend on lapse rates and wind speed. Waves most often form at inversions, boundaries between denser, colder surface air masses and warmer, less dense overlying air. (Sometimes this condition is called *lid* since it marks the upper limit for convec-

(Left) On October 10, 1947, Harland Ross easily gained 8,000 feet in a standing wave caused by the relatively low Inyo Mountains. Dust columns to the windward of each roll cloud facilitated study of the phenomenon.

(Right) On October 29, 1947, in a light plane with a passenger, Harland Ross climbed to 23,500 feet from 6,000 feet in less than eight minutes, as shown here by the dotted line.



John Robinson, holder of the American sailplane altitude and distance records, in the cockpit of his craft, with crew chief John Olley, at the 1948 Southwest Soaring Contest. Photograph by Photo Associates; engraving courtesy of the Soaring Society of America.

tive action in the air below.) Tropopause waves at the top of our weather-producing air belong to this family.

One further type of gravity wave not yet in the literature was observed April 8, 1948, at Buffalo. It was ahead of a low pressure trough moving from west to east, dense cirrus clouds forming an arch along the wave. A military type airplane from a neighboring research laboratory got in the lift of this wave at the 20,000 to 30,000-foot levels. Although throttled way back, the heavy ship continued to climb until finally the pilot abandoned the flight (his purpose was to maintain constant altitude). It is quite possible that this type of wave, forming and moving ahead of the low pressure trough, is the mechanism of the dangerous and somewhat mysterious prefrontal thundersquall, which occurs suddenly and without change of air mass.

Weather processes make sailplaning possible. We need more measures of the vertical air motions from which come our clouds and rain and hail and surprises. Pioneer souls in this country a half century ago brought the air age with gliders and began the study of air currents. Today, smart sailplane pilots are continually bringing new and valuable knowledge to meteorologists.

Weather Helps Establish Sailplane Records

JOHN ROBINSON, of Arcadia, California, shivered in below-zero temperatures as he set a new American altitude record of 33,300 feet on January 1, 1949, to become the holder of the two top American soaring records: altitude and distance. He was towed by a power plane to 10,000 feet and released west of Bishop, California, in the standing wave in the lee of the Sierras. Oxygen was required for three hours.

The American distance record was set on July 19, 1947, by the same combination, John Robinson and the Ross-Stephens single-place sailplane *Zanonia*. The skill with which aerodynamics and meteorology were applied to a record flight of 325 miles over Texas is shown by a digest from the May-June, 1949, issue of *Soaring*, in which Robinson describes his experiences:

It was 11:33 a.m. when the Stearman PT-17 towed me aloft, 2,000 feet over the airport. Cross-country progress was slow for the first 60 miles. Thermals were weak and more than half of the time was spent circling and drifting with the wind.

Glider pilots are not above accepting visible aids when it comes to locating the elusive thermal; consequently, with my altitude down to 1,200 feet above the ground, I was overjoyed when a "dust devil" appeared southeast of the highway. These dust whirls indicate a thermal touching the ground and picking up loose dust or sand. As I glided toward it, the dust whirl drifted over a green field and disappeared. By taking a bearing on its base location where last seen, and figuring its probable drift, I dove toward the spot. A sudden sharp gust hit, a quick circle, then it hit again. Twenty miles of straight gliding were over and the flight was saved. This was by far the strongest thermal of the day, and I was soon flying a very tight spiral, holding a bank of about 60° in order to stay close to the core where the lift was greatest. When the altimeter indicated more than 8,000 feet the climb slowed.

I left the highway at Haskell and met prompt retribution in the form of an altitude bandit, a strong downdraft which snatched away 2,000 precious feet. Happily, a strong "down" usually means a strong "up" is nearby, and the next thermal was strong. Enticing little cumulus clouds began to appear ahead and above. I reached cloudbase at 10,000 feet and swept onward at 80 to 85 mph. It was apparent that I had entered a different air mass, for the wind was now more easterly, not

(Continued on page 67)

WHEN SUMMER COMMENCES

S. S. VISHER

PROFESSOR OF GEOGRAPHY
INDIANA UNIVERSITY

SUPPLEMENTARY to "When Spring Arrives," in WEATHERWISE for April, the following brief text and three maps on when spring ends and summer commences may be of interest.

As the summer months are June, July, and August, summer is frequently said to start on June 1st. The other commonly mentioned precise date is June 21st, the summer solstice. When the beginning is set by the attainment of relatively warm temperatures, the date varies in different parts of the country. The

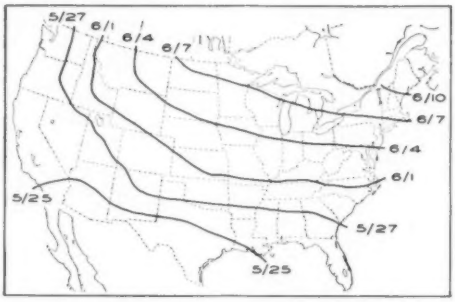


Fig. 1. Average dates of the starting of the warmest quarter of the year (summer).

accompanying maps illustrate the regional contrasts on three bases. Fig. 1 shows when the hottest quarter of the year commences according to daily temperature normals (the average of day and night for many years). It reveals that summer on this basis commences in late May in much of the South and far West; it commences about June 1st in a belt extending from North Carolina to Kansas and Idaho, and it starts about June 7th in the area extending from New York to North Dakota.

Summer is often thought of as the season when average temperatures are 68° or higher. Such a "summer" temperature is attained normally by May 1st in the deep South (Fig. 2), about June 1st in a belt from Maryland to Kansas, but not till after June 15th in much of the Northwest and West.

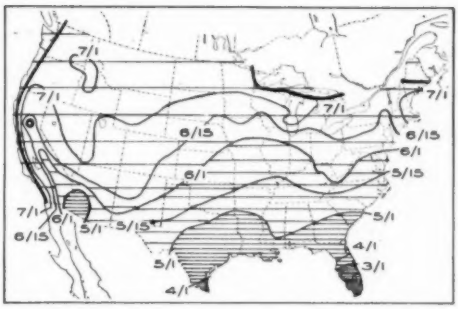


Fig. 2. Average dates when the daily normal temperatures rise to the summer level of 68° F.

When the daily temperature normals reach 75°, summer certainly has arrived. Fig. 3 shows that this high a temperature is normally attained in May in the South, sometime in June in a middle belt, but that in more than a third of the country such hot weather ("hot summer") is not attained at all in an average year.

These maps are original, based on abundant official data. They are to appear also in *Climatic Atlas of the United States* (in press).

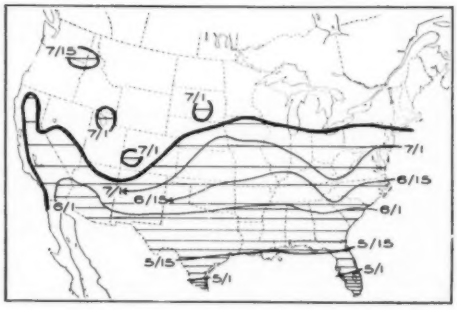


Fig. 3. Average dates when the daily normals of temperature reach 75° F.

GLOBAL WEATHER STATION

A new global weather control center that will be able to give complete forecasts for any part of the world has recently been established at Offutt Air Force Base, near Omaha, Nebraska. Experienced forecasters of the Air Weather Service have been assigned there, many of whom assisted in preparing the data for the recent globe-encircling flight of the B-50 bomber, *Lucky Lady II*.

The Donora Smog Disaster —
A Problem in Atmospheric Pollution

ROBERT D. FLETCHER, U. S. WEATHER BUREAU

POLLUTION of the air resulting from combustion processes of modern industry has become a major problem facing civilization. When certain meteorological conditions prevail over the proper topographical regions, especially in valleys and lowlands where large populations are often concentrated, pollution can cause disease, death, and disruption of the economic and social life of a community.

A critical meteorological situation developed during the last week of October, 1948, over southwestern Pennsylvania and, in particular, over the town of Donora, which lies at 761 feet above sea level in the relatively deep and narrow valley of the Monongahela River about 20 miles south-southeast of Pittsburgh. Near the end of a five-day period in

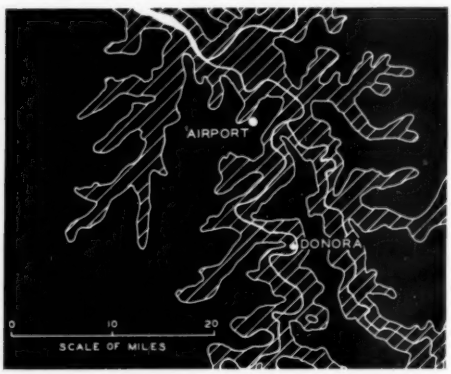


Fig. 1. The river valleys of the Pittsburgh-Donora region. The shaded areas are below 1,000 feet above sea level. The altitude of the airport is 1,250 feet, that of Donora 761 feet.

which an extraordinarily thick atmospheric pollution accumulated, 20 persons died and hundreds were stricken in and near Donora, according to newspaper reports, presumably as a result of the pollution. In this article, we shall briefly study the meteorology of the period — detailed investigations are under way by the U. S. Public Health Service and the U. S. Weather Bureau.

Donora lies near the center of a heavily industrialized region. That the topography is favorable for local concentration of smoke and gases is evident from Fig. 1, which shows the approximate course of the 1,000-foot elevation contour in southwestern Pennsylvania. It can be seen that if the bulk of the pollution is emitted at an elevation of, say, less than 1,000 feet, and if forces prevent the pollution from spreading upward, the space in which it is free to drift will be relatively small. The river valley and its tributary valleys can be compared, in such a case, with a tunnel having numerous "blind alley" tunnels as appendages. If the wind circulation happens to be very weak within the tunnel system, the constant emission of pollution will produce a steady accumulation of smoke and gases within the system. If the weak wind is steady as to direction, downwind locations within the tunnel system and not far from the bulk of the pollution sources will be the most vulnerable.

On October 26, 1948, an eastern-seaboard storm had receded and was being replaced by a polar anticyclone advancing from the west. During the day the high became established over the eastern states. It remained approximately in the same position for five days, during which the skies in western Pennsylvania were nearly cloudless and what low-level wind circulation existed produced a very weak, but fairly steady drift southeastward from the Pittsburgh area toward Donora. Fogs formed and persisted in the lowlands. In fact, considerable areas of fog were to be found over most of Pennsylvania and in parts of neighboring states. On October 31st, a weak frontal zone slowly moved into the area from the west, changed the wind to a southerly one with increased speeds, and brought cloudiness, rain, and an end to the disastrous combination of circumstances at Donora. The sequence of Weather Bureau maps for the critical period is illustrated in Fig. 2.

Aerological soundings are taken at 10 a.m. and 10 p.m. EST, at the nearby Pittsburgh

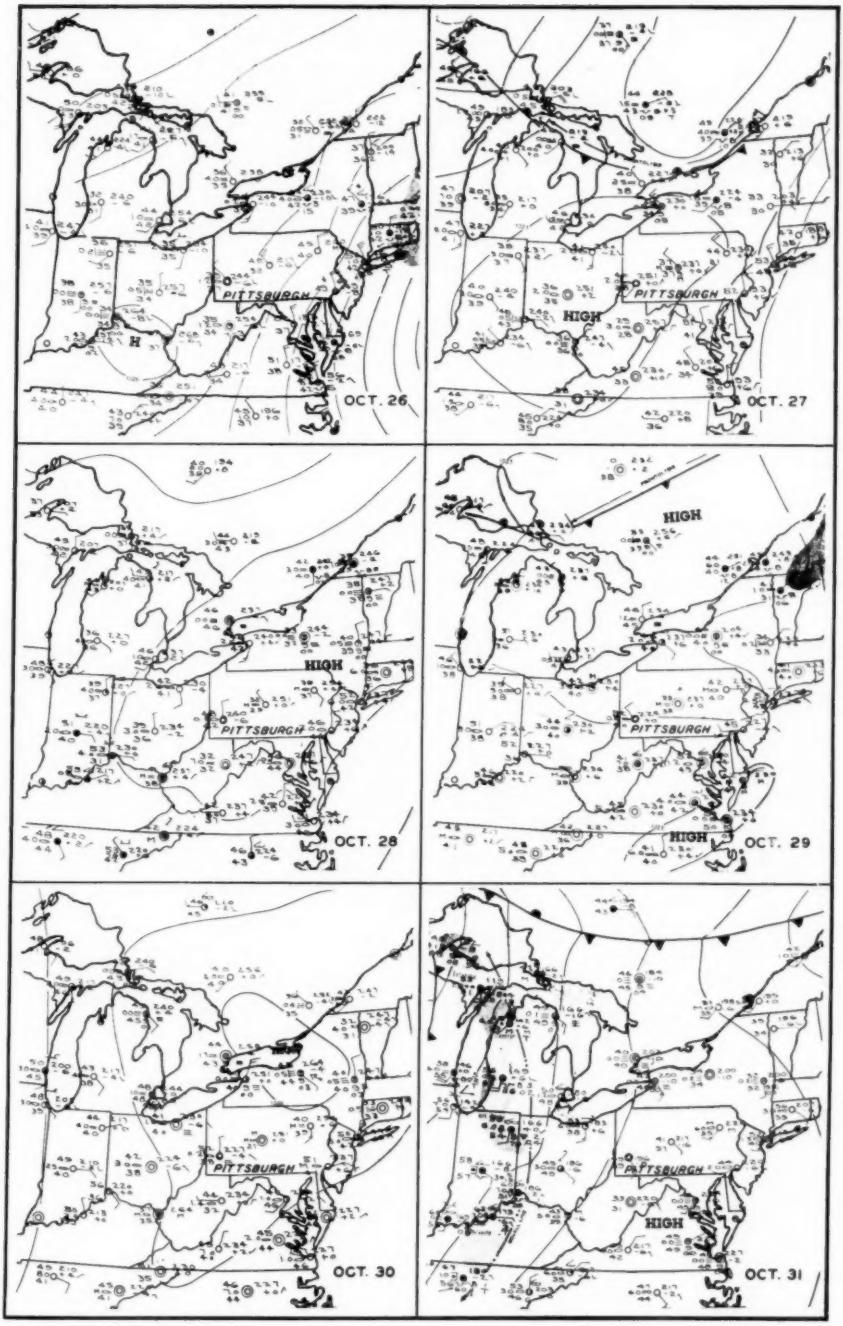


Fig. 2. Portions of the 0130 EST weather maps for the six days, October 26-31, 1948, inclusive. For simplicity, Pittsburgh is the only station name shown, and isotherms have been omitted.

Airport Weather Bureau station, located at an elevation of about 1,250 feet. Prior to and following the critical period, the lowest layers of air were characterized by a decrease of temperature with height. By evening of the 25th increasing stability was apparent, and

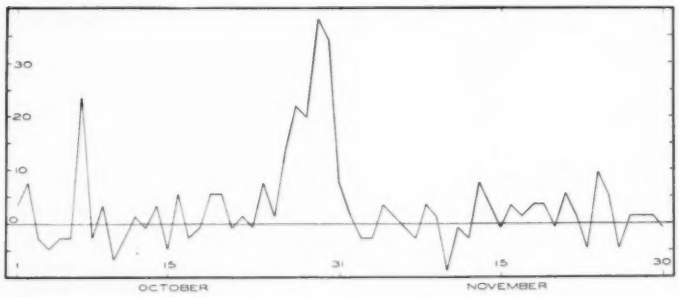


Fig. 3. Atmospheric stability as measured by noontime temperatures differences, Pittsburgh Airport minus Donora, October and November, 1949. The vertical scale is the excess in degrees Fahrenheit per thousand feet.

late on the 26th a surface inversion had formed. On the morning of the 27th, although considerable stability was present in the lowest layers, the base of the inversion was about 500 feet above the ground. From the evening of the 27th through the 31st a well-developed surface inversion was measured on every sounding.

The daily maximum, minimum, and noon temperatures are available from records of the co-operative observer station at Donora. In comparison with similar measurements made at the Pittsburgh Airport, the Donora values provide a striking illustration of the pronounced stability which dominated the Monongahela Valley during the critical period. The excess of vertical temperature gradient over the gradient given by the dry adiabatic lapse rate, a measure of the force which suppresses vertical motion of air, has been computed for the noon readings of the two stations for each day of October and November, 1948. Each vertical gradient was obtained by subtracting the Donora temperature from the Pittsburgh temperature and dividing the result by the difference in elevation between the stations. The excess values, in degrees Fahrenheit per thousand feet, are plotted in Fig. 3.

Immediately apparent is the great stability which prevailed during the period when severe atmospheric pollution persisted, October 26-30. Following a "peak" of stability on the 27th and a slight abatement on the 28th, greatest stability existed on the 29th and 30th. Eighteen of the 20 Donora deaths are reported to have occurred on the 30th. With the approach of the frontal zone on the 31st, stability returned to normal.

Similar stability computations for the Donora and Pittsburgh maximum and minimum temperatures, Fig. 4a-b, indicate that each noontime stability was fairly representative of the stability for the day. Further, computations for the surface and first significant level of each twice-daily Pittsburgh aerological sounding show considerable similarity between the stability above the airport and that within the river valley, Fig. 4c-d.

With regard to the atmospheric pollution problem, vertical stratification of temperature is significant largely because of its ability to indicate the degree to which vertical turbulent components of air movement are suppressed. With constant stability, however, a stronger wind moving over a ground surface will produce greater eddy components, and hence will act more strongly to thin out pollution

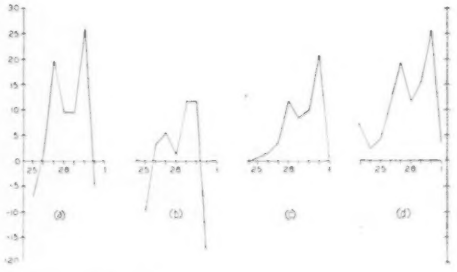


Fig. 4. For the critical period, October 25-31, 1948, stability in degrees Fahrenheit per thousand feet as measured by: (a) maximum daily temperatures, Donora and Pittsburgh Airport; (b) minimum daily temperatures; (c) 10 a.m. aerological soundings at Pittsburgh Airport; (d) 10 p.m. aerological soundings at Pittsburgh Airport.

through vertical spreading. The average wind is, of course, of prime importance as an agent that spreads pollution horizontally. It should be expected, therefore, that wind speed and pollution concentration are inversely related.

A wind-parameter graph, Fig. 5a, was constructed by averaging reciprocals of the recorded wind at the airport for each hour of the day. Its correspondence with the stability graph for the critical period is remarkable, including the maximum value on the 30th. While it is true that a large percentage of the variation in wind speed must have been due to variation in stability, the two factors being intimately related, it is probable that a significant portion of the variation of pollution concentration was due to variation in wind speed alone. The degree of significance of the wind parameter requires quantitative observations of the pollution concentration in the Donora area. No such observations were available for the present investigation.

WIND DATA, OCTOBER, 1948
PITTSBURGH AIRPORT AND DONORA, PA.

Date	*Time EST*	*Donora Surface*	*Airport Surface*	*Airport 2,000 ft.*
25	0400		7 N	11 N
	0958	NW	10 N	11 N
	1600		8 NW	25 NW
	2206		4 NW	9 NNW
26	1145	NW	6 W	4 NW
	1600		3 WSW	8 W
	2211		3 SE	7 N
27	0407		4 SSW	5 NW
	1005	SW	2 W	3 NW
	1620		2 ENE	4 N
	2208		4 SE	4 ESE
28	0435		8 NE	9 ENE
	1027	NW	2 NNE	2 ENE
	1610		3 NNW	6 N
	2159		4 NNW	3 NNW
29	0412		0 NW	2 N
	1003	NW	0 NNE	4 NE
	1615		3 NNW	5 N
	2208		6 N	5 N
30	0400		3 ESE	5 E
	1001	SE	2 E	3 NE
	1600		3 NNE	2 N
	2203		5 SE	3 S
31	0400		10 SSE	14 SSW
	1000	W	10 S	12 SW
	1605		8 SSW	19 SSW

Donora direction is prevailing direction for the day at Donora, elevation 761 feet. Airport surface is at 1,250 feet; 2,000-foot are pilot-balloon observations. Wind speed is in miles per hour.

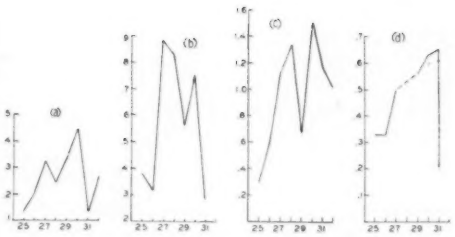


Fig. 5. For the critical period, October 25-31, 1948: (a) the pollution-spreading parameter from hourly surface winds at the Pittsburgh Airport, reciprocal of the daily harmonic average wind in miles per hour; (b) the vertical-pollution-spreading parameter from surface and 2,000-foot winds, Pittsburgh Airport pilot-balloon soundings, reciprocal of the daily harmonic average wind shear in miles per hour per thousand feet; (c) the visibility parameter, reciprocal of the daily average visibility in miles at the Pittsburgh Airport; (d) the smoke-top parameter, from in-flight reports, reciprocal of smoke-top heights above sea level in thousands of feet.

The stronger the vertical shear of the wind, the greater is the vertical spreading of pollution. Wind-shear data, in miles per hour per thousand feet, were obtained from the surface and 2,000-foot mean sea level readings of the four daily pilot-balloon observations of the airport for October 25-31. From Fig. 5b, containing the reciprocals of the daily harmonic average wind shears, it may be seen that the trend of the shear parameter again resembles that of the stability. Further study is required to determine the extent to which shear variations contributed independently to variations in pollution concentration.

Surface and 2,000-foot winds at the airport, given in the table, show considerable variation in direction. Although most of the air currents for the period October 25-29 were from northerly quadrants, during the most disastrous day, October 30th, light southeasterly winds seem to have predominated. Under the influence of the frontal zone, the winds of the 31st quite clearly became southerly, with increased speeds. As regards wind direction, more positive conclusions again must await a much more detailed study.

Visibility at the airport was restricted during the entire critical period. Fig. 5c, containing the reciprocals of the daily average visibilities, shows that visibility lowered as the pollution concentrations probably increased at Donora. Before satisfactory rela-

tions between visibility and pollution concentrations can be ascertained, however, the visibility-reducing effects of humidity must be evaluated.

The lower the smoke top the greater should be the concentration of pollution, other factors being equal. Fragmentary pilot reports collected at Pittsburgh indicate a steady lowering of the smoke top to a minimum at the end of the critical period. At 9:50 a.m. of the 31st, the top was at its lowest value, 1,500 to 1,600 feet above mean sea level. At 11 a.m. it began to rise to between 1,600 and 1,700 feet, and at 11:18 a.m. a pilot flying at 5,000 feet over Cumberland, Maryland, reported that he was in smoke and haze with a visibility of five miles.

The Donora occurrence of 1948 was not a unique one. A sequence of meteorological circumstances from October 4th to 14th, in 1923, had also brought about serious smog conditions in the vicinity of Donora. The synoptic situation was quite similar to that of last fall. Following passage of a cold front, a large polar anticyclone moved into the area surrounding southwestern Pennsylvania, stagnated for many days, and was finally displaced by a frontal system from the west. There is a report of yet another serious smog period at Donora on October 7-18, 1938; again the stagnating polar anticyclone dominated the weather maps. In that case, however, there were two such anticyclones, one persisting from the 9th through the 12th and the other from the 14th through the 18th.

One of the worst smog occurrences of record happened not in this country, but in Belgium. To the west of the city of Liege, the valley of the Meuse River is deep and narrow, its floor lying perhaps 250 to 300 feet below the surrounding countryside. On December 1, 1930, a large polar anticyclone moved into the area and stagnated. Low-level winds were weak, but were directed such that smoke from the factories of Liege and environs drifted southwestward along the river valley. Persistent fogs formed in the lowlands. Most of the smoke appears to have been trapped within the tunnel formed by the valley walls and the temperature inversion at the top of the fog. There is some evidence that smoke above the inversion was partially carried down into the tunnel through the action of gravity and the complicated mechanism of atmospheric turbulence. Persistence of great quantities of pollution and, probably, chemical changes due to prolonged contact of the pollution with the water of the fog, brought tragic results. On the 4th and 5th, 63 persons died and hundreds were stricken along the Meuse between Liege and the town of Huy. On December 6th, the polar anticyclone which had dominated Belgium for five days moved eastward as a frontal system advanced from the west. The inversion and fog dissipated, general rains began, and the period of intense atmospheric pollution was ended.

From the preliminary findings of this article can be drawn several conclusions which may assist in the forecasting of severe smog conditions and may aid in economic planning from the standpoint of serious smog potentialities and probabilities.

1. Pollution sources must be nearby and active.

2. Past occurrences suggest that the fall season, especially the month of October, is the most likely for serious smog conditions.

3. If topography permits low-level trapping, then potentially dangerous areas can be identified.

4. The lower layers of the atmosphere should have great stability, and winds should be weak, yet directed from pollution-source regions toward areas of potential danger.

5. Humidity in the lowest layers apparently should be such that fogs can form and persist.

6. The polar anticyclone is most likely to produce the stagnant conditions required for great pollution concentrations, but the possibility of the requirements being met by another model should not be overlooked, and should be investigated.

7. The stagnant conditions should persist for a considerable period; four days seems to be a reasonable minimum. If it is proven that extended durations are requisite, forecasting a dangerous smog situation should consist not so much in determining when the meteorological conditions will begin as in deciding how long existing conditions will persist. It is not uncommon for the critical meteorological model to be centered over a geographical area for a day or two — it is the necessity for persistence of the model for four days or more which fortunately makes rare occurrences of the disastrous smog situations.

Thunderstorm Today?

– – TRY A PROBABILITY FORECAST – –

SAUL PRICE, SHORT RANGE FORECAST DEVELOPMENT SECTION
UNITED STATES WEATHER BUREAU

SO ACCUSTOMED have most of us become to the usual wording of the weather forecast: *fair and warmer; scattered showers today followed by clearing and colder tonight*, that we may be a little surprised to learn that present research is pointing toward the possibility that a quite different kind of weather forecast may be both feasible and, in some cases, very useful: one which would tell us *what chance there is of getting a particular kind of weather at a given place during a specified period of time.*

Perhaps the best way to introduce some of the principles and uses of this kind of weather forecast is to consider the problem of a rural telephone company which is anxious to reduce its maintenance bill, especially during the summertime thunderstorm season. Although individual thunderstorms are less destructive than the widespread snow and sleet storms of winter, their electrical effects and far greater frequency make them a most troublesome source of complaints regarding interrupted service, while their localization results in the highest repair cost per unit of damage.

For these reasons the company has found it necessary to keep service crews overtime or on stand-by at a number of its outlying sub-stations whenever the forecasts of the local Weather Bureau indicate the possibility of a thunderstorm within their service area. This is, of course, an expensive procedure, and all sorts of alternatives, including radar detection of storms, have been considered, but rejected as too costly or ineffective.

Last year, a conference of company engineers reached the startling conclusion that revenue from further expansion of service to additional areas could no longer be expected to compensate for increasing summertime maintenance costs. In other words, the point of diminishing returns had been reached.

At this juncture a weather consultant was called in and the problem presented to him. In order to cut summertime maintenance costs to the bone, he was told, the company needed a forecast, 8 to 10 hours in advance, of the time and place at which a thunderstorm would occur within its service area. Could this be done?

Of course the weather consultant stated that it could not, and doubted that he could improve the service they were already getting from the local Weather Bureau office. But there was another possibility. Had they ever considered the usefulness to them of a different kind of weather forecast, one which would give them, on each summer day, the actual numerical odds that a thunderstorm would occur within their service area? Then, by applying these odds, by balancing the expense of preparing for a thunderstorm against the risk of being caught unprepared, the company could decide in advance, on the basis of past experience, the cheapest course of action to follow for any particular probability of a thunderstorm.

To the company engineers this was a novel but an intriguing idea, and a preliminary maintenance plan was arranged. As the chance of a thunderstorm increased, more and more crews were alerted, until, when the odds reached seven out of 10 or higher, the preparation for emergency service would equal that previously made *whenever* a thunderstorm was forecast.

If, *in the long run*, the odds worked out as predicted, company engineers estimated that a reduction in costs could be made which, while less than that possible with "perfect" forecasts, would still make further expansions of service financially worthwhile.

It must be admitted at this point that the company, its problems, and even the weather consultant are all fictitious and were presented for purposes of illustration. However, so closely do they resemble the very real problems and weather consultants of actual companies, that it becomes extremely im-

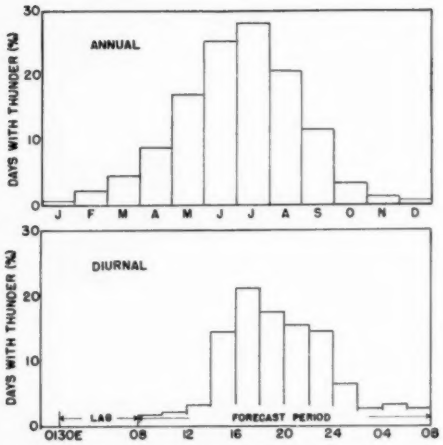


Fig. 1. Annual and diurnal distributions of thunderstorms at Washington, D. C., showing the time-lag between the observations used and the beginning of the forecast period.

portant to ask whether solutions of the kind suggested are possible and how they may be achieved.

These questions have been receiving extensive study for the past several years at the United States Weather Bureau's Short Range Forecast Development Section, since forecasts in terms of weather probabilities would be of great potential value to a wide variety of enterprises, as diverse as concrete laying, irrigation, cranberry growing, and hydroelectric power.

Among the problems investigated by this group is one very similar to that faced by our imaginary telephone company: to estimate each day during July (using data available no later than 0130 EST) the numerical odds that a thunderstorm would occur at Washington, D. C., or in its immediate vicinity during the 24 hours beginning at 0800 EST. These conditions and a summary of thunderstorm climatology at Washington, D. C., are shown in Fig. 1.

A quantitative point of view was maintained throughout. We asked not merely whether a general connection could be found between selected meteorological factors and subsequent thunderstorms, but also how strong that relationship was and how it was affected by other factors operating at the same time. This led to the careful study of many weather maps and soundings for the months of July, 1939 to 1948, and the tabulation of daily values for a large number of weather variables.

As might have been expected, certain factors, such as steep lapse rates and approaching fronts, were often found to have preceded thunderstorms at Washington, while others, such as dry air aloft and anticyclonic pressure patterns, appeared to have been unfavorable.

It was particularly interesting to note how often thunderstorms had occurred following early-morning observations that showed abundant surface moisture and falling pressure at Washington and to the west. Extensive testing demonstrated that these conditions could be well represented by two simple measures: *wet-bulb temperature*, which is an index of moisture, and is also associated with stability and other important air-mass characteristics; and *the algebraic sum of the 3-hour pressure changes or barometric tendency sum at Washington and Pittsburgh*, which contains information about the movements of the large-scale pressure systems as well as the smaller perturbations which, although hard to find on the weather map, appear to be important in "triggering" thunderstorms when other conditions are favorable. Figs. 2 and 3 clearly show how the proportion of thunderstorm days increases with high wet-bulb temperatures and falling pressure. The upper broken curve in each figure was derived directly from the lower and represents

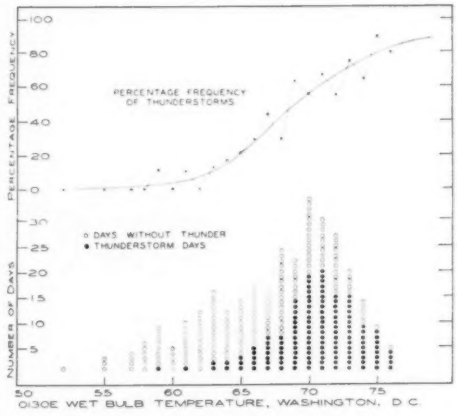


Fig. 2. The relationship of the 0130 EST wet-bulb temperature to subsequent thunderstorms at Washington, in July for 10 years, 1939-1948.

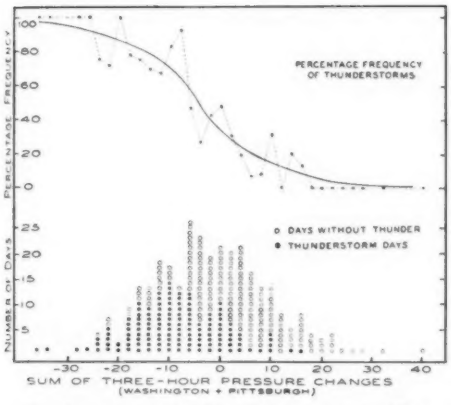


Fig. 3. The relationship of the sum of the Washington and Pittsburgh three-hour pressure changes at 0130 EST to subsequent thunderstorms at Washington.

the percentage of days which had thunderstorms. Fig. 2, for example, shows that out of 310 July days, 1939 to 1948, nine had wet-bulb temperatures of 75 degrees at 0130 EST, and that, in eight of these nine cases, or about 89 per cent of the time, a thunderstorm occurred at Washington, D. C., during the 24 hours beginning the following 0800 EST. The unbroken curves in Figs. 2 and 3 were obtained by eye smoothing.

By assuming a certain constancy in weather relationships, we may readily regard these smoothed curves of thunderstorm frequencies as representing also *future thunderstorm probabilities.*

Since, on any day, the estimate based on wet-bulb temperature (Fig. 2) is likely to disagree with that based on the barometric tendency (Fig. 3), the obvious next step is to reconcile these differences and obtain a combined estimate of thunderstorm probability better than that given by either alone. This is shown in the scatter diagram of Fig. 4. Each day is plotted at its observed wet-bulb temperature and pressure change sum as a symbol representing the weather which occurred on that day. For example, July 22, 1948, with a wet-bulb temperature of 74° and a barometric tendency of −14 (in tenths of millibars), and on which a thunderstorm occurred, may be found at (74, −14) as a filled circle. Note the clustering of thunderstorm days in that portion of the chart characterized by high wet bulbs and falling pressure.

The isopleths of Fig. 4 were drawn by eye to indicate the frequency of thunderstorms among the 310 plotted points. Thus, about 30 per cent of the points lying between the lines labeled "20" and "40" are thunderstorm days, and there is a similar correspondence between the other isopleths and the plotted data.

By assuming, as we did before, that these lines describe not only the distribution of the

(Continued on page 67)

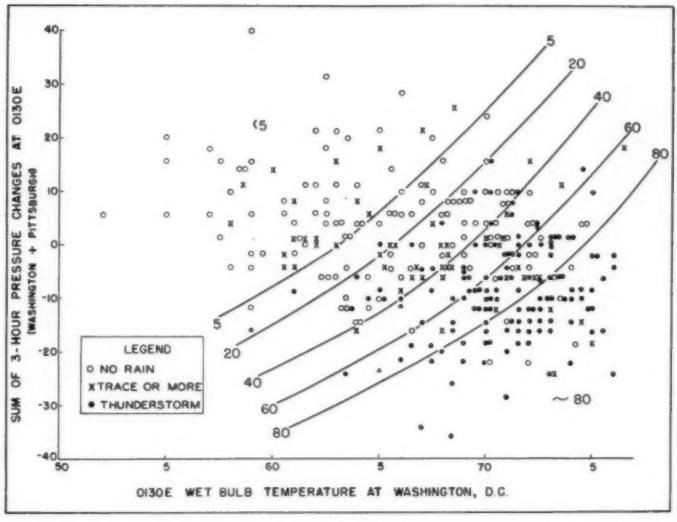


Fig. 4. The combined (joint) relationship of 0130 wet-bulb temperature and barometric tendency to subsequent thunderstorms at Washington, D. C. The diagonal lines (isopleths) indicate the percentage frequency of thunderstorm days in the various parts of the chart.

FORECASTING THE WEATHER

The Weather Types of North America — 3

ROBERT D. ELLIOTT
AMERICAN INSTITUTE OF AEROLOGICAL RESEARCH

IN THE APRIL ISSUE of **Weatherwise,** there were presented the three North American **B north** types (**Bn-a**, **Bn-b** and **Bn-c**) and **B south (Bs)**. These are all meridional flow types with the common feature of an upper-level crest in the west (reflected by a Great Basin high at the surface) and a trough in the east. Now we shall consider three additional meridional flow types, two of which resemble the **B north** and one the **A** (**Weatherwise,** February, 1949).

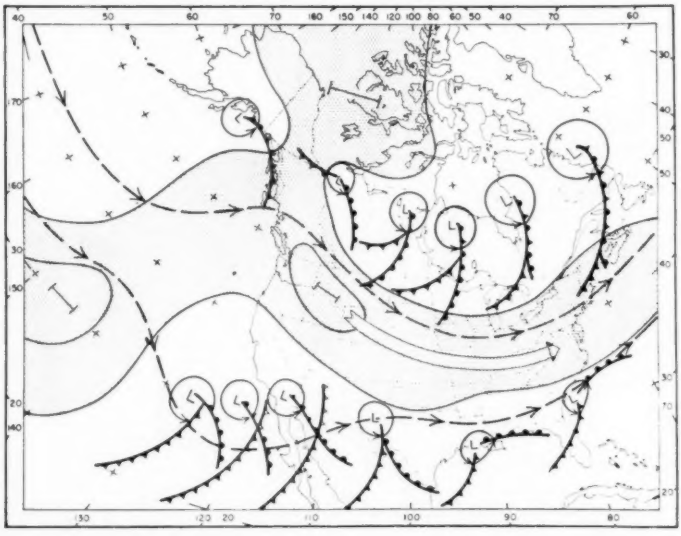
At times the Great Basin high, so characteristic of **Bn** types, becomes displaced as far north as British Columbia and thus permits storms to enter the Pacific Coast south of the high. This is a characteristic of **C** type weather, an infrequent but tremendously important event in the western part of the United States because of the abnormal weather events associated with it. It produces some of California's "unusual" weather, which so often occasions comment in the press at the time of its occurrence. Rainfall is quite heavy, often causing floods in the coastal plains. On the other hand, Washington and Oregon, which accept precipitation every day or so as a normal winter occurrence, experience clear dry weather.

One might immediately conclude that this type represents an unusual southward displacement of Pacific storm tracks. However, the picture is not quite this simple because often, simultaneously, storms enter Alaska and move eastward, then southeastward into Canada. In view of this feature, it is more logical to say that the normal storm track is split into two parts, separated by the Great Basin high. There exist two distinctive **C** types; one **CL**, in which the Basin high is of moderate intensity with the northerly storm track crossing southern Alaska and northern British Columbia; the other, **CH**, in which the Basin high is exceptionally strong and centered well to the north in British Columbia. In the second type, the northern storm track is north of Alaska and usually not apparent on the daily weather map. The southern track is through the southwestern United States.

The third meridional flow type to be described in this article, type **D**, is characterized by a deep trough aloft just off the West Coast, and a crest far to the west in the Pacific, with a lesser crest in eastern United States. It is most closely related to type **A**, and differs from it in that the mean upper-level flow pattern is shifted farther to the west.

The observant reader will perhaps have noted

TYPE CL OF NORTH AMERICAN WEATHER TYPES



a certain spatial relationship between the meridional types depicted in this and the previous two installments — they have different mean trough and crest positions. In the table below, each successive type shows an increased westward displacement of the major upper-level crest.

Meridional Flow Type	*Western Crest Position*	*Eastern Trough Position*
Bn-a	115° to 120° west	about 90° west
Bn-b	115° to 120° west	about 90° west
CL	about 125° west	about 85° west
CH	about 130° west	70° to 80° west
Bn-c	about 135° west	about 100° west
A	145° to 150° west	105° to 115° west
D	about 160° west	130° to 135° west

It will be noted that the eastern trough is only in general farther west for each successive type and that there are two notable exceptions, **CL** and **CH**. In these types the western crest is exceptionally strong, and therefore the distance from crest to trough (half wave length) is greater than normal, the eastern troughs being farther east than in **Bn-a** or **Bn-b** types. Also, a trough exists directly south of the **CL** and **CH** type western crests. To the east of (downstream from) this deformity the upper-level flow converges quite markedly.

In a subsequent issue, we shall consider a number of zonal flow types. These will be shown to fall into a similar sequence, in which, however, the upper-level flow pattern displacements for successive types are from north to south rather than from east to west.

As in the preceding cases, the types are represented by schematic diagrams, each diagram covering the number of days required for one cyclone to advance eastward across North America. The mean upper-level flow for each type is indicated by dashed lines and arrows. Areas of persistent high pressure are delineated by stippling and double arrows indicate trajectories of major polar outbreaks. Successive daily positions of a single cyclone and its associated frontal system are shown in conventional weather map fashion. The descriptive material pertains to the winter season. Type characteristics vary only slightly with season and the well-known seasonal climatic differences are primarily the result of seasonal variations in the frequencies of occurrence of the types.

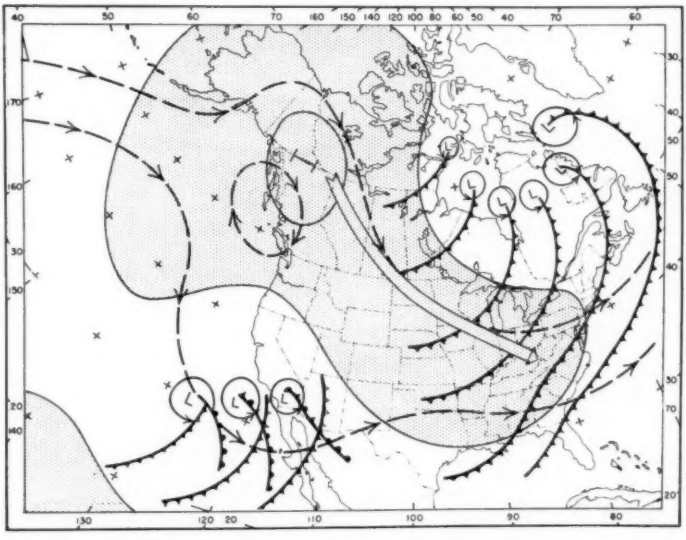
TYPE CL

CL is a meridional flow type in which the upper-level crest has a mean position at about 125° west and the eastern mean trough position is at about 85° west. A distinctive feature is the presence of a trough at low altitudes at 120° to 125° west, almost due south of the western crest position.

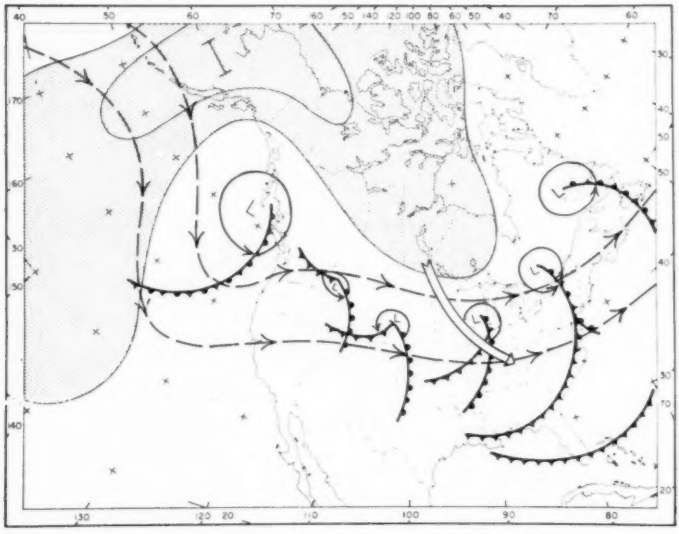
At the surface, a Great Basin anticyclone occupies the position indicated in the diagram, well to the north of normal. It will be noticed immediately that there are two cyclone tracks on the diagram, one to the north and one to the south of the Basin high and its eastward extension. As indicated by the double arrow, the high migrates eastward, and, being composed of cold air, can be considered as a sort of polar outbreak. A new high then develops over the northern Great Basin to replace it.

The cyclonic center which moves eastward along the northern path has an appreciable ef-

TYPE CH OF NORTH AMERICAN WEATHER TYPES



TYPE D OF NORTH AMERICAN WEATHER TYPES



fect upon the weather in Canada only, except for relatively minor frontal cloudiness and precipitation in extreme north central and northeastern United States. The cyclonic center which moves eastward along the southern path, on the other hand, produces quite important amounts of rainfall (and snowfall at higher elevations) in southern California and the southern Great Basin area. This type and the related **C**H type produce the heaviest precipitation known in southern California, yet northern California and Washington and Oregon experience little or no precipitation. The eastward movement of the southern storm is quite erratic, and very often it appears on the weather map as a series of several closely spaced waves.

Precipitation is generally below normal except in the Southwest where it is much above normal, and in the Gulf states where it is above normal in a few spots. Exceptionally dry weather is experienced in the Pacific Northwest.

Temperatures are generally near or above normal, although the preceding type may play an important role in establishing the temperature anomaly in the West.

Type **C**L occurs much more frequently in the winter than in any other season.

TYPE CH

CH is a meridional flow type in which the upper-level pattern is characterized by a mean crest position at about 130° west and an eastern trough position at 70° to 80° west. The crest is so extreme in character that a closed center appears at upper levels, as indicated in the diagram. Another trough appears at 115° to 120° west, at very low latitudes, and south of the western crest.

At the surface the outstanding feature is the presence of a strong and persistent high pressure center over northern British Columbia. Central pressures are usually 1040 mb or more. A portion of this high, which is quite cold, moves southeastward as a polar outbreak. The magnitude of the outbreak is so great that the cyclonic center moving into southern California along the southern storm track is completely blocked from further eastward progress by the time it reaches New Mexico. There probably exists a northern storm track around northern Alaska, but the first place where ordinary synoptic weather charts show cyclonic activity is over Hudson's Bay and in Quebec. The cold front associated with this activity sweeps far south into the eastern United States, bringing a mass of cold air to these regions.

Precipitation is much above normal in southern California and in New Mexico and Arizona. Elsewhere it is generally below normal, especially so in the Pacific Northwest, British Columbia, and most of Alaska, where high pressure maintains clear skies.

Temperatures are above normal along the southern Pacific Coast, but elsewhere are generally below normal, especially in the Great Plains states.

This type occurs, with few exceptions, in the winter only. In the mountains of southern California, relatively warm and moist tropical Pacific air produces high-level convective activity over the mountains that has in the past proven a trap for aviators, the incidence of aircraft

accidents being exceptionally high with this and the related **CL** weather type.

TYPE D

This meridional flow type is characterized by a well-marked crest aloft in the Pacific with a mean position at about 160° west. The major trough is at 130° to 135° west, but there is also a minor crest near 105° west and a minor trough near 80° west. On the whole, the pattern resembles that for type **A** (**Weatherwise,** February, 1949), but shifted somewhat to the west.

At the surface, the eastern lobe of the Pacific high cell is unusual in form, extending northward from its normal position and apparently merging with the polar continental high pressure area over Alaska. This combination resembles a horseshoe. A semi-permanent low pressure center exists off the British Columbia coast, and from this a frontal system moves eastward, inducing the formation of a new wave center in Montana that is steered eastward through the north central and northeastern United States; it produces fair amounts of precipitation. A series of fronts striking the West Coast brings considerable precipitation there and injects quite cool Pacific air masses into the West Coast area. A minor polar outbreak follows the low in the East bringing cold weather to the Great Lakes and northeastern states.

Precipitation during this type averages above normal along the West Coast. Normal to a little above normal amounts of precipitation occur in the north central and northeastern states. Elsewhere precipitation is below normal.

Temperatures average below normal in the West Coast states and in the north central states; elsewhere they are above normal.

The type characteristics described above are for the winter season but this type occurs more frequently, although with less intense characteristics, in the summer half of the year.

THUNDERSTORM TODAY? — TRY A PROBABILITY FORECAST

(Continued from page 63)

days actually plotted on Fig. 4, but of all other July days as well, they may be treated as *isopleths of probability* and used for estimating the chance of a thunderstorm on any future July day. To illustrate this, let us suppose that on July 1, 1949, the 0130 EST observations of wet-bulb temperature and barometric tendency at Washington are 68° and +10, respectively. Plotting this point on Fig. 4, we find that it lies almost on the "20" line, showing that only about 20 per cent of the days which fell in this approximate area *in the past* turned out to have thunderstorms. Therefore, we would forecast that there were also only two chances in 10 that a thunderstorm would occur on this occasion. Whoever received this forecast would then, as with our imaginary telephone company, have to decide for himself what course of action to take.

To see if these odds worked out, test "forecasts" were made for many days in June and August of past years, with very satisfactory results.

Simple scatter-diagram techniques, like those described in this article, offer the amateur meteorologist an opportunity to test his own ideas about weather relationships in his own locality. He should not, however, expect to achieve useful results without much careful thought and experimentation.

WEATHER HELPS ESTABLISH SAILPLANE RECORDS

(Continued from page 54)

so strong. A much steeper lapse rate was forming vigorous thermals.

At 5:40 p.m. I was hovering over my preannounced goal, Big Spring, Texas, 210 miles from Wichita Falls, with 5,500 feet of unused altitude. A little help from the elements would take me to Midland, about 40 miles further. One last thermal just before Midland pushed the altimeter from 7,000 to 9,000 feet. This cinched Midland and Odessa too, 20 miles farther on.

A large column of smoke was sighted on the horizon directly ahead. It was coming from one of Texas' many carbon plants near Penwell, 15 miles southwest of Odessa. Here was a man-made thermal, and it went up to 8,000 feet and could be stretched 35 miles to Pyote Air Base. Here a familiar smoke line showed up on the horizon, coming from Pyote. The ship dove in only 500 feet above the ground, but the resulting lift was small, weak, and difficult to stay in. Twenty-two minutes of circling in and out produced a gain of only 1,500 feet.

I glided 14 miles in 13 minutes with that last 2,000 feet of altitude, producing a glide ratio of 35 to 1 in very smooth air with a slight tailwind, to land three miles short of Barstow, Texas, at 8:10 p.m.

NATIONAL SOARING CONTEST AT ELMIRA

The 16th Annual National Soaring Contest will take place July 2-10 at Harris Hill, Elmira, N. Y., and the Soaring Society of America invites all amateur and professional meteorologists to attend and see firsthand how glider pilots utilize the energy of the weather. A technical conference with special emphasis on meteorology is scheduled to begin at about 4:00 p.m., July 8th. Anyone desiring to present a paper at this conference may write Mr. Ben Shupack, 141 Utterby Road, Malverne, N. Y.

WORKSHOP FOR WEATHERMEN

CONDUCTED BY CHARLES A. LAIRD

How to Construct a Simple Electrometer

THE "ELECTRONIC" instrument described this month is comparatively easy to build and adjust. Don't let the fact that it contains a radio-tube circuit bother you. The circuit is much simpler than the most elementary radio receiver. Tube and parts are readily available, and construction is for the most part merely a matter of wiring the components together.

The completed instrument is called an electrometer. It will show free electrical charges in the air — charges that vary with certain weather conditions.* The meter will indicate potentials in the vicinity of thunderstorms, even when such storms are a number of miles from the location of the electrometer. It may be considered an aid to forecasting, and its indication of electric fields, even in clear weather, proves it to be an interesting and useful instrument for the amateur weather station.

The tube used is a 1N5, and its filament is lighted with an ordinary 1.5-volt dry-cell (A) battery. The pickup, on which the charge is induced, is a piece of heavy copper or brass wire, one end of which is pointed and elevated at least five feet above a house or a supporting structure. The other end of this conductor is connected to the control (No. 1) grid of the 1N5. Nothing should touch this conductor at points of support, except small blocks of good insulating material, such as the plastic known as polystyrene.

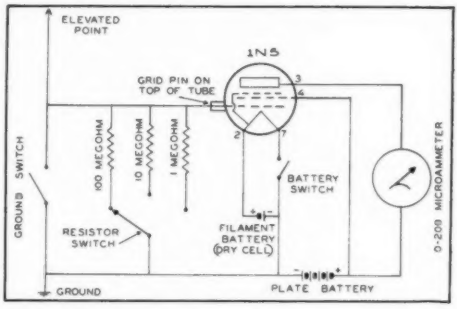
You may place small rain shields of some plastic material over these support points so that the insulating blocks cannot get wet. Even a small amount of water on the insulating blocks will make the apparatus go completely dead.

The electrometer components may be mounted on a wood or metal base, and the assembly (battery, etc.) put in a metal box with the indicating meter and battery switch on the top or on one side. The box should be grounded. The plate or B-battery has its negative side connected to the negative side of the filament or A-battery. Its positive side is connected to the 1N5's screen grid and also the positive terminal of the indicating meter, a 0-200 microammeter. The other terminal of the meter goes to the plate of the tube. A small 22½-volt B-battery is used.

You may try several sizes of grid resistors, such as 100 megohms, 10 megohms, and one megohm. The highest resistance will work best in relatively quiet rain, while the one megohm is most suitable during thunderstorms. You may use a clip arrangement for inserting the various resistances or, better still, use a single-pole, triple-throw switch for easier and quicker changeover, as shown in the diagram.

The minus side of the B-battery is connected to a water pipe or ground rod. You'd better install a heavy single-pole knife switch to ground the inductor, in case a thunderstorm passes directly overhead. Otherwise, heavy currents may damage the apparatus.

This apparatus measures, in a very rough way, the electric field in the atmosphere near the observing station. In fair weather, variations of the meter reading will not be very great, but under certain conditions of precipitation, large fluctuations may be observed. For example, as a thunderstorm approaches, activity of the meter will be observed to increase gradually, and when a lightning discharge takes place, the meter will suddenly jump by a number of divisions. Larger current readings correspond in general to an increased negative charge overhead, whereas decreases from the normal are produced by positive charges overhead.

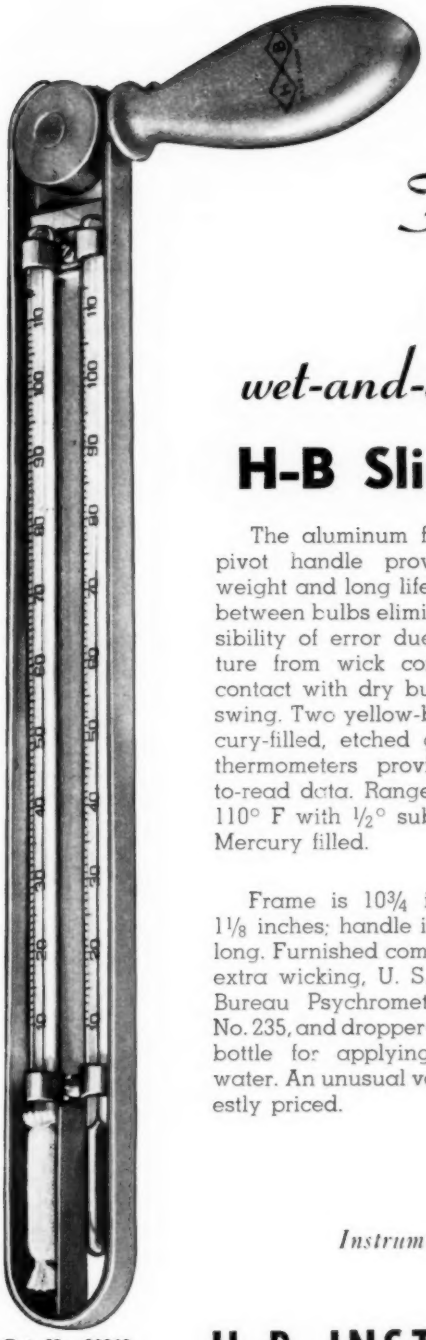


The method of wiring the electrometer described in this article. Numbers at tube refer to socket connections (octal socket-underside).

Even in the absence of thunderstorms, but with precipitation, free electrical charge is frequently in the atmosphere, and it will modify the reading in the meter in accordance with the charges overhead. In such weather, the sudden jumps in the meter reading observed in thunderstorms are seldom present.

Actual calibration, in terms of electrostatic voltages, is quite complicated, and the amateur weatherman interested in trying this should consult publications on electric field measurements. But relative meter fluctuations, as shown on the microammeter, will prove of interest, and charts can be drawn up comparing meter readings during periods of rain, clear weather, and thunderstorms.

*See, for example, U. S. Patent #1,919,215 to Ross Gunn, issued July 25, 1933.



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MANUAL OF CLOUD FORMS AND CODES FOR STATES OF THE SKY

U. S. Weather Bureau. Circular S, 2nd Edition, 1949. 43 pages, 25 cents from Superintendent of Documents, Washington 25, D. C.

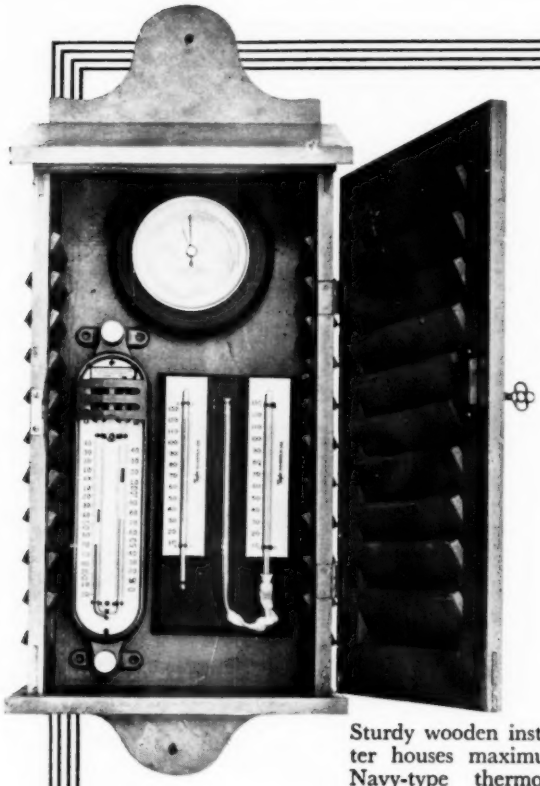
THIS NEW ISSUE of well-known Circular S was necessary because of changes voted by the International Meteorological Organization in 1947, to become effective January 1, 1949. The new booklet is of 43 pages, of sufficient size for the display of 47 cloud photographs, as well as official text describing the different cloud types and code-numbered states of the sky.

Definitions and descriptions of the forms of clouds occupy the first seven pages, in double-column format. These are virtually a reprint of the corresponding section of the International Atlas of Clouds and States of the Sky, 1932, but with amplifications found helpful to observers in the Weather Bureau and deletions of details here and there that hardly seemed necessary. Although no references are made in this section to the photographs that accompany the following section, the legends of the photographs permit the observer to find the pictures that illustrate the different genera, species, and varieties described.

The remainder of the booklet is devoted to specifications of international cloud codes CL, CM, and CH. First, the technical and non-technical specifications adopted by the IMO are given verbatim. Then each of the nontechnical specifications is repeated and usually followed with a few amplifying paragraphs and one to four photographs, each with a legend briefly pointing out salient features important in distinguishing the state of the sky illustrated. Although a few of the photographs are repeated from the 1st edition, the great majority were taken from the photographic collections of the U. S. Weather Bureau, the Canadian Meteorological Service, and Harvard's Blue Hill Observatory. More than 1,000 cloud photographs were considered in making the small selection. Though a good many are beautiful pictures, some, like the skies they are chosen to depict, have a certain drabness.

While many users of this book may wish for more discussion of differences and for explanations as well as descriptions of the differences between the several cloud forms and states of the sky, others will find its streamlined brevity time-saving in day-to-day use in identifying clouds and their formations.

CHARLES F. BROOKS
Blue Hill Meteorological Observatory



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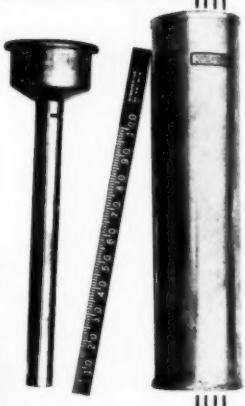

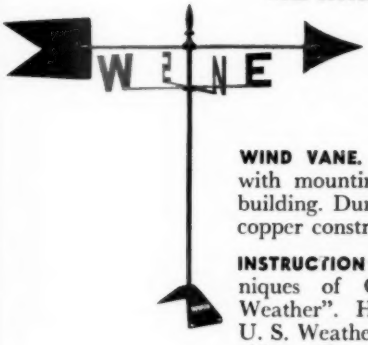

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